Telecommunication Systems Planning

A major element of the ITS mission is to serve as a central Federal resource to assist other Government agencies in planning, designing, maintaining, and improving their telecommunications systems and networks. Over the years, ITS has developed a seven-step telecommunications planning process that helps to organize and facilitate these activities.

The seven steps are: (1) requirements definition (e.g., mission, business plan, connectivity and traffic profiles, and safety and security needs); (2) review of existing systems (from an operational, performance, and cost perspective); (3) review and assessment of internal factors (i.e., those within agency control); (4) review and assessment of external factors (e.g., Office of Management and Budget, General Services Administration, and other applicable guidelines and directives); (5) technology assessment (i.e., what is available, or will be available); (6) development of telecommunications alternatives (based on the data developed from all other planning activities); and (7) formulation of an integrated plan (based on the selection of the best alternative). A particular technical project may involve all or only some of these activities, depending on the plan's scope and the agency's specific needs.

Areas of Emphasis

Intelligent Transportation Systems Planning

The Institute characterizes the electromagnetic spectrum environment, develops propagation models, analyzes electromagnetic compatibility, and examines new telecommunication technologies to support the development of intelligent transportation systems. Projects are funded by the Federal Highway Administration (FHWA).

Advanced Systems Planning

The Institute performs engineering analyses to determine the spectrum efficiencies associated with current communication systems and planned implementations of positive train separation and advanced train control systems. Projects are funded by the Federal Railroad Administration.

Multimedia Performance Handbook

The Institute contributes to the advancement of the National Information Infrastructure through development and promulgation of interactive, CD-ROM-based guidelines and applications for multimedia system procurement and assessment. Projects are funded by NTIA and the National Communications System.

Telecommunications Analysis Services

The Institute provides network-based public access to the latest ITS research results, engineering models, and databases supporting wireless telecommunications system design and evaluation. The project is funded by NTIA and by users of the services on a cost-reimbursable basis.

Augmented Global Positioning System

The Institute determines optimal locations for differential global positioning system reference stations, examines the needs of system users, and performs field evaluations of existing beacon system stations, to support the design and optimization of a nationwide navigation and positioning service. Projects are funded by the Department of Transportation and the FHWA.

PCS Networks

The Institute develops and applies computer-based simulation tools in assessing the performance and interoperability of emerging personal communications services equipment. Projects are funded by NTIA.

Intelligent Transportation Systems Planning

Outputs

- Electromagnetic compatibility analysis of intelligent transportation systems and subsystems.
- Support for intelligent transportation systems committees for communications, spectrum, and electromagnetic compatibility.

Surface transportation in the United States is becoming more of a problem as traffic congestion continues to increase. For many areas of the country, building more roads is financially and environmentally prohibitive. Traffic congestion in the United States causes a loss in productivity, increased accidents, wasted energy, and increased vehicle emissions. Intelligent transportation systems use computer and telecommunications technology to provide information to travelers about road and transit travel conditions and can monitor, guide, and control the operation of vehicles. By applying these techniques, these systems can improve safety, reduce congestion, enhance mobility, minimize environmental impact, save energy, and promote economic productivity in a transportation system. Maintaining safety on the Nation's streets and highways is also a primary concern. Intelligent transportation systems can enable travelers to make more informed choices about routes, times, and modes of travel. With intelligent transportation systems, authorities can better manage transportation systems traffic. Some examples include the ability to: rapidly respond to road accidents to restore traffic flow, redirect traffic away from the most congested routes, provide information on ride sharing, provide traffic control at intersections and on street networks, meter ramps on freeways, reserve lanes for buses and high-occupancy vehicles, and provide automatic in-transit commercial vehicle weigh-in and toll collection.

Intelligent transportation systems include a wide range of electrical and electronic devices and equipment. These devices and equipment, coupled with external signals and interference from external sources represent a complex interactive electromagnetic environment with emitters and receptors. The operation of radio communications equipment and other electronic devices around vehicles equipped with these systems could cause interference to the resident automotive electronic systems and the electronic equipment in the rest of the environment.

Electromagnetic compatibility (EMC) is a primary factor in the performance, safety, and effective operation of intelligent transportation systems. EMC is the ability of electronic equipment to achieve a specified level of operability in an uncontrolled environment. It involves the orchestration and integration of system components in a fashion that will control interference coupling, and is a primary consideration in intelligent transportation system design. The Institute has participated in many activities that address EMC during the initial conception, design, development and testing phases of intelligent transportation systems.

Recent activities and accomplishments on intelligent transportation systems at the Institute include:

1. Measurements of high-level electric field strength in the roadway environment. The results will be used to determine the operating environment for intelligent transportation subsystems.

2. An analysis of the electronic toll and traffic management (ETTM) system that determined the potential EMC problems that might result if large numbers of ETTM systems were placed into operation near 2.4 and 5.8 GHz. The characteristics of the roadway environment near 2.4 and 5.8 GHz were examined. This included Government radars and other industrial, scientific, and medical (ISM) systems. The compatibility of a generic ETTM system with these existing radars and ISM systems was determined.

3. An assessment of propagation models for use in the analysis and design of intelligent transportation subsystems. This assessment was performed to evaluate the capability of using existing models. Recommendations for future development in propagation models for intelligent transportation systems in the roadway environment were made.

4. An evaluation of an AM subcarrier operational test that is currently being performed for a proposed advanced traveler information system (ATIS). The system would be used to disseminate information to travelers in the rural roadway environment.

5. An analysis of AM subcarrier systems that will support the design and field testing of the AM subcarrier evaluation effort for ATIS.

6. Measurement and verification testing of FM subcarrier system coverage. This testing will support the prediction of area coverage for an FM subcarrier system for ATIS in rural and urban environments.

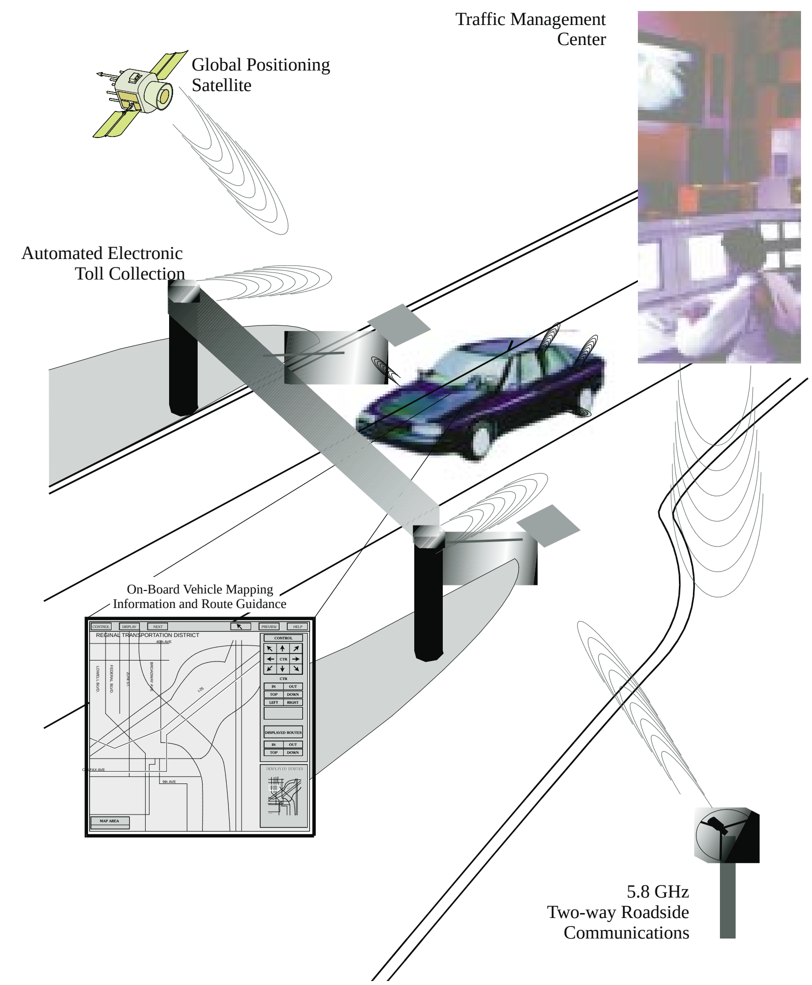
7. FM subcarrier coverage and performance prediction of selected U.S. areas. These predictions will be made for regions that differ dramatically in terrain and population density. These regions may implement the FM subcarrier form of ATIS.

8. Development of radio wave propagation models for the analysis of automated toll collection systems, short range communication systems, and ATIS.

9. Ongoing support for intelligent transportation systems communications committees, including the High-speed Data Subcommittee, Intelligent Transportation Systems Telecommunications Committee, and the Transportation Research Board.

Future activities at the Institute include: (1) characterization and measurement of the electromagnetic environment, (2) spectrum planning, (3) propagation model development, (4) determination of suitable new communications technology for intelligent transportation systems, (5) prediction of radio coverage for communication systems, (6) selection and establishment of an EMC requirement standard for intelligent transportation systems, (7) creation of an EMC control plan, (8) selection and development of an EMC testing standard for intelligent transportation systems, and (9) creation of an EMC test plan. The Institute also will be involved in system architecture evaluation in the EMC concept and design phases and will assure EMC for demonstration projects during the course of systems development.

The Figure is a pictorial representation of the ATIS concepts of electronic traffic management and toll collection; in-vehicle information and route guidance for navigation with the global positioning system and low frequency differential correction signals; and updated traffic and road condition information from a traffic management center via an FM and AM subcarrier data broadcast.



Pictorial representation of Advanced Traffic Information System for intelligent transportation systems.

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Advanced Systems Planning

Outputs

- Measurements of railroad radio channel use.
- Estimates of bandwidth requirements for the positive train separation system.
- Evaluation of total radio spectrum needed for future railroad operations.

The Federal Railroad Administration (FRA) promotes safe railroad transportation and encourages infrastructure and technology to realize that goal. ITS has supported the FRA by evaluating the telecommunications aspects of safe train movement.

The Association of American Railroads and the Railways Association of Canada have proposed specifications for the North American advanced train control system (ATCS). ATCS is a data communication-based system that transmits command and control information between dispatch centers, locomotives, track maintenance vehicles, and wayside devices. It is intended to provide more economical, efficient, and safer train movement in North America.

Most railroads have adopted an incremental approach to implementing the complex ATCS by conducting small-scale experiments and pilot projects to become more familiar with the technology and its impact. System interoperability between railroads is a key issue because locomotives owned by one railroad commonly run on track owned by another. The Burlington Northern (BN) and Union Pacific (UP) railroads have initiated a joint pilot program to implement and test technology designed to achieve positive train separation (PTS). The safety objectives associated with PTS include prevention of collisions between trains, prevention of collisions between trains and track maintenance vehicles, and prevention of speeding by trains (Figure 1).

The pilot program will be implemented on over 863 miles of BN/UP track in Washington and Oregon. Compatible equipment on BN and UP locomotives and compatible software in the two railroads' operations centers will allow "handoff" of trains from one operation center to another without interruption or degradation of the on-board safety functions.

The system provides a nonvital safety overlay to existing railroad traffic control and signaling systems by enforcing movement authorities and speed restrictions for PTS-equipped trains. The PTS system accomplishes this through the server, locomotive, and communications segments. The primary function of the server segment is to determine enforceable movement authorities and speed limits. This information is transmitted to the locomotive segment through the communications segment, which incorporates both wireline and wireless networks. The locomotive segment warns the crew of violations, and if the crew does not respond, the train is automatically slowed or stopped.

Adequate radio frequency spectrum is crucial for the implementation of PTS systems. ITS consulted with the FRA throughout the Federal Communications Commission (FCC) rulemaking on "refarming" the VHF and UHF bands containing railroad allocations. PTS and ATCS, when fully implemented by all railroads, will add to the required spectrum needed by the railroad industry. ITS has begun the following three-step process to evaluate that need: (1) determine current use of the railroad-allocated spectrum; (2) determine the spectrum needed to fully implement PTS/ATCS; and (3) estimate the future need of the railroads for voice communications, PTS/ATCS, and new services such as video communications.

During the first step, ITS measured the spectrum used by current railroad channel assignments. Three cities, where radio communications are expected to be heavy, were selected for the measurements:

Figure 1. High-speed passenger train with wayside equipment to monitor passing trains (photograph courtesy of the Federal Railroad Administration).

Chicago, Illinois; St. Louis, Missouri; and Kansas City, Missouri and Kansas. An ITS measurement van was located near railroad yards in each city and measurements were made continuously for about one week at each site. During the measurement period, the channels were monitored with a spectrum analyzer by sweeping across all channels about once per second. This gave information on the channels that were in use at each site. By tallying the time period that each channel was used from sweep to sweep, message statistics for the radio channels were gathered. Figure 2 shows a channel utilization plot for the Chicago, Illinois site over a 24-hr period of the railroad band from 160.215-161.565 MHz. Figure 3 shows the distribution of message durations over the 24-hr period. Most of the traffic lasted for only a few seconds as would be expected of the dispatch-to-mobile communications. Some of the traffic lasted for minutes and included instructions from the dispatch to the conductor of the locomotives.

The second step of the study included an evaluation of the spectrum required to support a fully implemented, nationwide PTS/ATCS. This process estimated the size and number of messages transmitted from a train, the associated wayside equipment, and the affected track forces, starting with train initiation and ending with train termination. The message traffic was scaled to include all locomotives, wayside equipment, and track forces that may be transmitted from one base or repeater station. From this total message traffic estimate, the required bandwidth to support the traffic was calculated.

The third step is to complete the evaluation, based upon results of the first two steps and to project the need by the railroads for new services. Because much of the railroad operations include linking locomotives and rail cars, detecting defects such as cargo overhanging rail cars, and checking track conditions in front of the locomotive, video services will play a considerable role in the future of railroad communications. A report will be prepared estimating the total need of radio spectrum by the railroad industry.

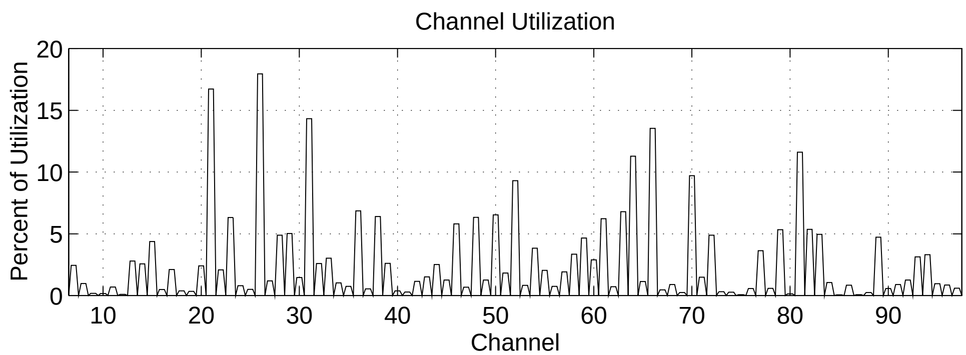

Figure 2. Relative radio channel utilization for the Chicago, Illinois railroad measurement site.

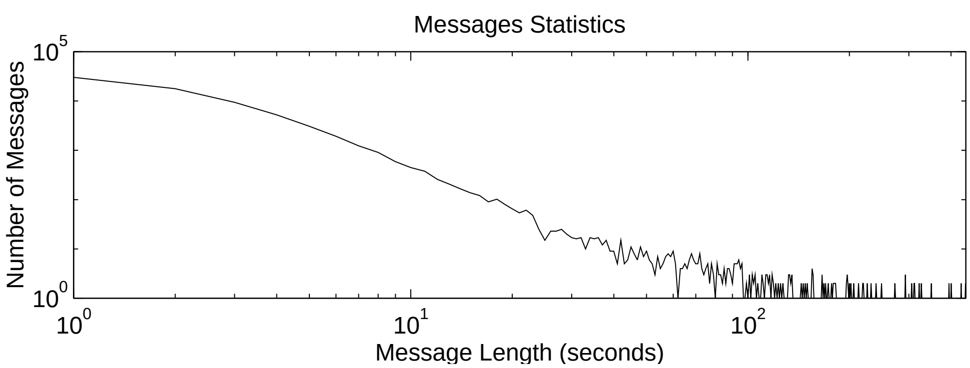

Figure 3. Distribution of message durations over the 24-hr period for the Chicago railroad measurement site.

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Multimedia Performance Handbook

Outputs

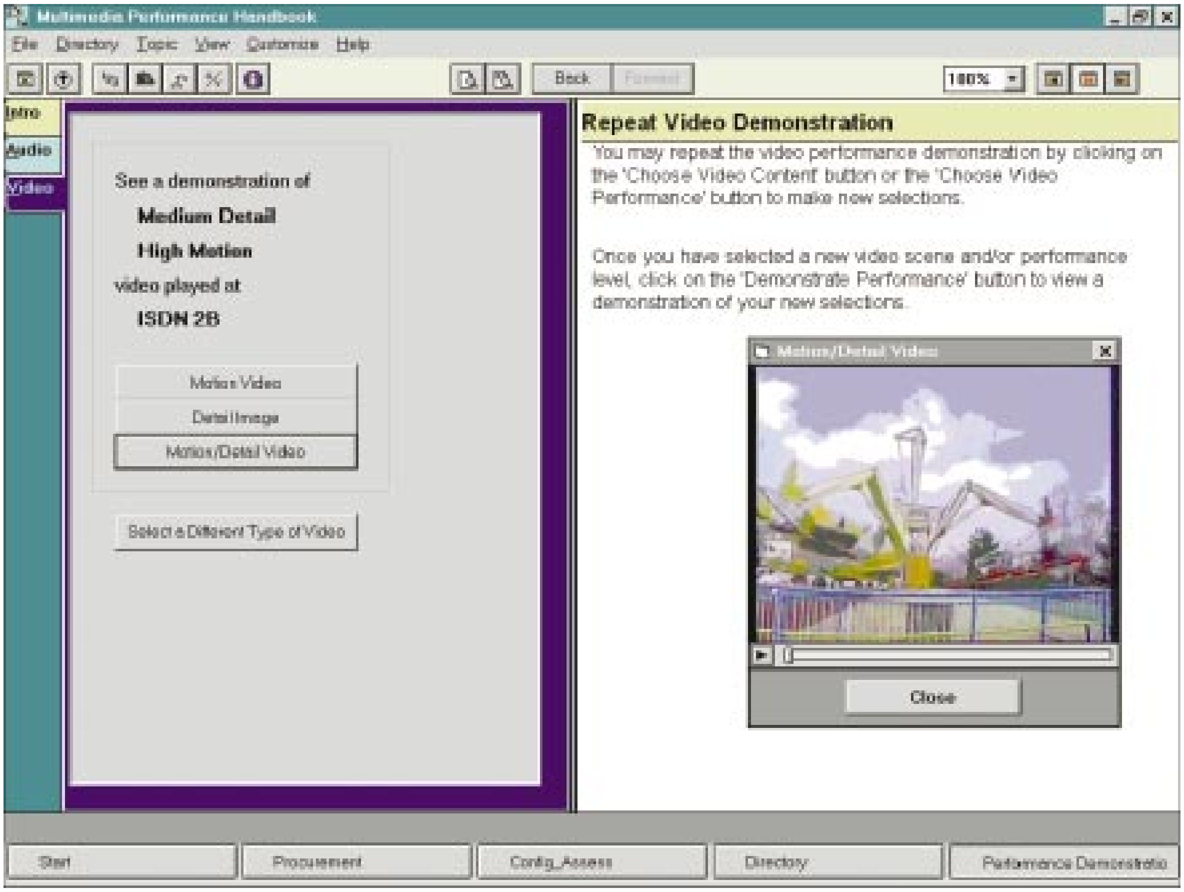
- Application of objective quality measures to multimedia services.
- Interactive Applets for procurement specification and configuration assessment.
- Tutorial and reference material on multimedia performance assessment.

Several years ago, ITS technical staff members recognized the need for consumer-oriented information concerning the performance of multimedia communication systems, equipment, and services. They foresaw that such information would find application in the procurement of multimedia products, in product acceptance testing after procurement, and in the maintenance of products after installation. Much of the necessary information had been or was being produced in the ITS program of telecommunications quality research, but additional product-specific information and more comprehensive selection criteria were needed. For example, ITS had been involved for several years in developing techniques for objective, technology-independent measurement of video image quality. While the resulting information was extremely valuable, consumers also wanted information concerning the image quality of specific video monitors and other video equipment. ITS sought and received support from the National Communications System (NCS) to develop a more comprehensive quality assessment tool. This product, known as the *Multimedia Performance Handbook*, originally was envisioned as a printed report that would undergo frequent (and sometimes extensive) revisions to reflect changes in technology. However, ITS engineers soon decided that a more flexible and effective means of presenting this information would be an interactive multimedia data access application implemented on a CD-ROM.

A first prototype of the Handbook was produced in FY 95. This product integrated the use of audio, video, graphical, and hyperlinked text in the context of an interactive graphical user interface to present required technical information in a user-friendly manner. Two new versions of the Handbook have subsequently been produced, each with increased functionality and larger information bases. In its complete form, the Handbook will provide a wealth of technical information and many specific examples to assist users in making effective decisions in the specification and procurement of multimedia communication systems. The Handbook's extensive use of audio, video, and graphical presentations greatly enhances the impact and value of its technical content. Hyperlinking of key text allows users to skim familiar material while delving more deeply into other topics. The Handbook can be used both in a linear fashion (like a book read cover to cover) and in a nonlinear fashion (like a book browsed randomly). Users may employ each of several Applets (small application programs that act as interactive assistants) to solve particular problems or to gain knowledge in particular areas. Applets can be accessed from designated *Reference/Tutorial* sections or (by clicking on a *Library* button) from any other point in the Handbook.

The Handbook implements two complementary functional modes: the *Procurement* mode and the *Configuration Assessment* mode. The *Procurement* mode is implemented as a large Applet that assists users in the specification of a multimedia system for a particular application. This mode specifies appropriate performance metrics for multimedia equipment and services. The understanding and proper specification of these performance metrics can help ensure that a procured multimedia system economically meets the quality requirements of the intended application. After selecting various options, the Procurement Applet displays a spreadsheet of suggested performance specifications. While providing the Applet with information leading to the specification, users can learn more about the quality aspects of the selected multimedia application.

The Figure shows a screen image from the Performance Demonstration Applet. This Applet allows the user to interactively specify the characteristics of a system, and then subsequently hear or see how their specification affects system performance. The operation of this Applet illustrates one of the Handbook's most valuable features: the use of real audio and video clips, derived from commonly available multimedia communications systems and



Example screen from the NCS Multimedia Performance Handbook.

equipment, to provide a realistic view of product performance before any product is procured.

The *Configuration Assessment* mode of the *Multimedia Performance Handbook* is designed to allow a user of multimedia services and equipment to determine the level of performance that can be expected from a particular configuration of multimedia service environments. The Configuration Assessment Applet of the Handbook can help answer the question, for example, "What will head-and-shoulders video look like if my communications path includes a PSTN modem at 28.8 kbps, a wireless link at 9.6 kbps, and an ISDN connection at 128 kbps?" The user can see a simulation of what the video might look like, obtain an estimate of the cost of such a system, and develop a spreadsheet of values for applicable quality metrics to ensure that required quality levels are met. Such capabilities will be useful both in procurement specifications and in product-acceptance testing.

The *Multimedia Performance Handbook* shows great promise for use by consumers as an interactive tool in the procurement of multimedia communications systems, equipment, and services. The Handbook combines innovative use of multimedia programming techniques, unique ITS-developed performance measurement technologies, and a broad view of telecommunications to produce a tool that will systematically provide the specification and assessment of multimedia systems in Government and private sector user organizations. It also represents a model of how ITS and other research organizations may present technical information in the future.

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Telecommunications Analysis Services

Outputs

- Easy access for U.S. industry and Government agencies to the latest ITS research results and engineering models and databases.
- Broad applications in telecommunication system design and evaluation of broadcast, mobile, and radar systems.
- Standardized method of system analysis for comparing competing designs for proposed telecommunication services.

Telecommunications Analysis Services (TA Services) gives industry and Government agencies access to the latest ITS research and engineering on a reimbursable basis. It uses a series of computer programs designed for users with minimal computer expertise or in-depth knowledge of radio propagation. The services are updated as new data and methodologies are developed by the Institute's engineering and research programs.

Currently available are: on-line terrain data with 3-arc-seconds (90 m) resolution for much of the world and 5-min resolution data for the entire world; the 1990 census data; Federal Communications Commission (FCC) databases; and geographic information systems (GIS) databases. Other Government databases and reports become available through a bulletin board service to all TA Services users as they are developed. For more information on available programs see the Tools and Facilities section of this report or call the contact listed below.

TA Services currently is focusing on the development of a model for use in advanced television analysis (high-definition television, advanced television, and digital television). This model allows the user to create scenarios of desired and undesired station mixes. The model maintains a catalog of television stations and advanced television stations from which these scenarios are made. Results of analyses show those areas of new interference and the population and households within those areas.

TA Services continues to develop models in the GIS environment for personal communications services (PCS). A GIS efficiently captures, stores, updates, manipulates, analyzes, and displays all forms of geographically referenced information. The use of GIS has grown substantially over the past several years; business, Government, and academia now employ GIS in many different applications. As a result, databases necessary for telecommunication system analysis are now becoming available in forms easily imported into the GIS environment. These databases include terrain, roads, communications infrastructure, building locations and footprints, land type and use, and many others. These databases can be maintained in commonly used and available relational database management systems (RDBMS) that can be connected to the GIS or placed into the GIS RDBMS. This greatly reduces the amount of database development necessary in PCS modeling.

Information on building heights and vegetation is needed for short-path models; however, it is not commonly available. Some city and county governments are beginning to enhance their GIS databases to include this data, and this trend is expected to continue. Software is available and under development that allows a user to import digital stereo photographs taken from aircraft at relatively low altitudes or even spacecraft. With sufficient photo quality, this data can be used to create three-dimensional surfaces for the GIS with accuracies on the order of a meter or less. This will greatly reduce the cost of developing databases with the accuracies necessary to ensure reliable analysis results.

The PCS model currently under development at ITS allows a user to select a city or region of interest that has a database developed and imported into the model. Once on board, this environment can be displayed in two or three dimensions as shown in Figures 1 and 2, respectively. A user can create a database of transmitters and antenna patterns from which analysis scenarios can be created. Transmitters can be described easily and placed either by defining the latitude and longitude or zooming in or out on the map and selecting the location of the transmitter. The GIS software reads the location from the map and stores it in the transmitter definition table. Antenna patterns can be imported, entered in table form, or drawn on the screen by a user as shown in Figure 3. The user can then give the pattern a name and store it in a personal catalog for future use.

Figure 1. Two-dimensional view of Boulder, Colorado from the TA Services PCS model.

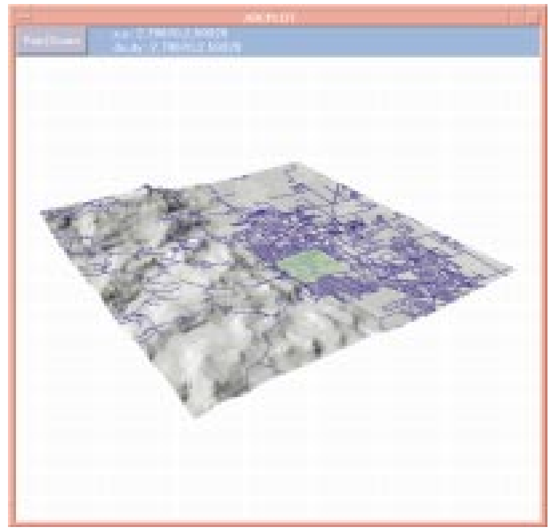

Figure 2. Three-dimensional view of Boulder, Colorado from the TA Services PCS model.

Scenarios created by a user consist of a set of transmitters, antennas, and models chosen to produce propagation results for a region of interest. Models include a road-guided path loss model, an over-building model, and a time-domain model. The model also allows the user to see all line-of-sight regions. The model has an analysis menu that allows the user to override the selection of appropriate models in the transmitter definition table and force a view of only one model for all transmitters. This menu also controls the results and options for viewing data. The model has a plot menu which allows the user to zoom in, out, left, right, up, or down in the view area and to turn on or off the option to view each cell's data value. From this menu the user also can select contours and the colors of each contour in all subsequent output result displays. Figure 4 shows the coverage of a PCS transmitter located on a courtyard between buildings in downtown Boulder, Colorado. Figures 1 and 4 show the roads, blocks, and building outlines of downtown and were imported into the GIS model from a CAD package used by the City of Boulder for city planning.

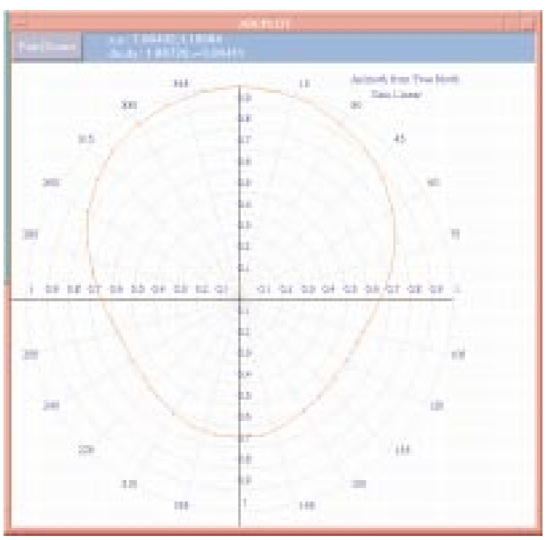

Figure 3. Antenna pattern from the user catalog in the TA Services PCS model.

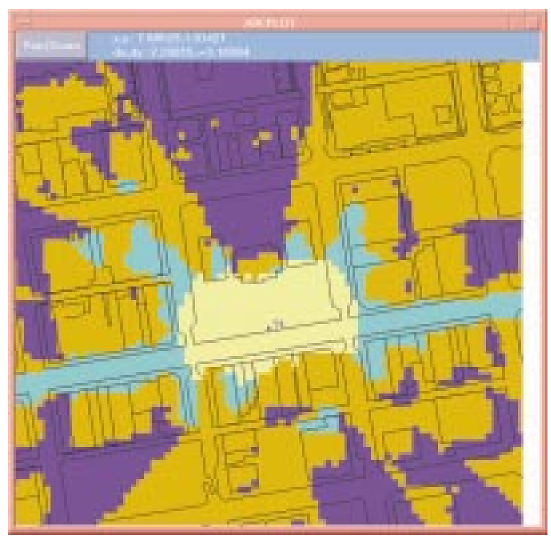

Figure 4. Model output for the Boulder, Colorado scenario in the TA Services PCS model.

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Augmented Global Positioning System

Outputs

- Verification of the performance of existing differential GPS reference stations.
- Planning of the number and location of differential GPS reference stations required to provide nationwide signal coverage.
- Installation guidelines for differential GPS reference stations.

The NAVSTAR global positioning system (GPS) is a space-based radionavigation system that is operated for the Federal Government by the Department of Defense (DOD) and jointly managed by the DOD and Department of Transportation (DOT). NAVSTAR is a constellation of 24 satellites in 6 orbital planes; it provides accurate three-dimensional position, velocity, and precise time to users worldwide, 24 hrs per day. GPS originally was developed as a military enhancement system. Although still used in this capacity, GPS also provides significant benefits to the civilian community. In an effort to provide GPS service to the greatest number of users while ensuring that national security interests are protected, two GPS services are provided. The precise positioning service (PPS) provides full system accuracy to military users. The standard positioning service (SPS) is available for civilian use but has less accurate positioning capability than PPS.

The SPS accuracy of 100 m does not meet most civilian navigation and positioning requirements. Various augmentations to GPS are used to provide increased accuracy and integrity of the SPS signal. One form of augmentation, differential GPS (DGPS), can provide 1- to 10-m accuracy for dynamic applications and better than 1-m accuracy for static users. In NTIA Special Publication 94-30, "A technical report to the Secretary of Transportation on a national approach to augmented GPS services," ITS recommended implementation of a low frequency/medium frequency radio beacon system, modeled after the U.S. Coast Guard's (USCG) local area DGPS, to provide nationwide coverage of DGPS for surface applications (DeBolt et al., 1995). The Institute is now conducting a study, sponsored by the Federal Highway Administration, to determine the optimum location and operating parameters of the DGPS reference stations required to provide this national navigation and positioning service (NNPS) to all surface users across the nation. The use of NNPS will have an enormous impact on a diverse set of uses including ocean and land transportation, surveying and mapping, farming, waterway dredging, recreation, emergency location and rescue operations, and many others that have not yet been identified.

DGPS is a land-based system consisting of four main components, as shown in Figure 1.

1. A reference station, placed at a precisely surveyed position, that receives and processes GPS satellite position information from orbiting GPS satellites, calculates corrections from the known position, and broadcasts these corrections via a radiobeacon to participating DGPS users in the radiobeacon's coverage area.

2. A control station, that remotely monitors and controls the DGPS reference stations via data communications lines.

3. A communications link, that provides data communications between the reference stations and the control stations.

4. User equipment, consisting of a GPS receiver and a radiobeacon receiver, that automatically applies the corrections to received GPS position information to achieve position accuracies of better than 10 m.

DGPS reference stations currently operating or planned by the USCG and the U.S. Army Corps of Engineers provide coverage of the radiobeacon DGPS signal for coastal areas, harbors, and inland waterways. This existing capability provides the DGPS signal to a majority of the nation (Figure 2).

ITS has recommended increasing the capability of this existing system by installing DGPS reference stations at Ground Wave Emergency Network (GWEN) sites, owned by the Air Force Air Combat Command. The GWEN system is an existing Federal Government asset that is scheduled for decommissioning in the same time frame that the DGPS radiobeacon system would be installed. Use

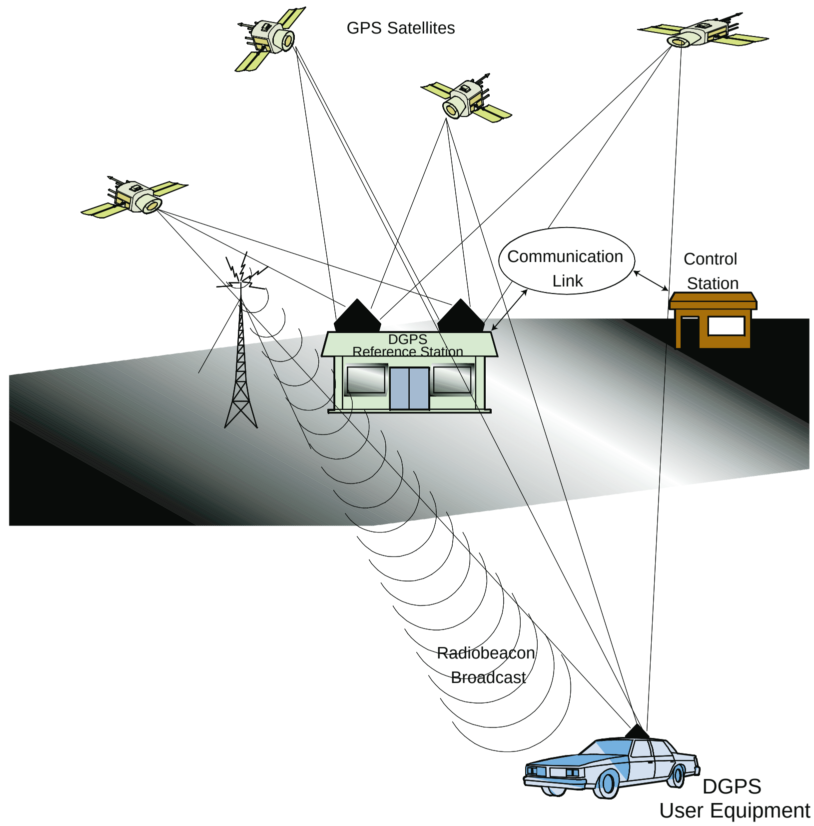

Figure 1. DGPS system architecture.

of the GWEN sites would provide a cost-effective method of implementing nationwide coverage of the DGPS signal. It would avoid the cost associated with decommissioning the sites, and the cost and delay of land acquisition and environmental impact statements required for additional DGPS reference stations. The combination of the existing DGPS reference stations and the additional stations at 15 of the GWEN locations will provide radiobeacon signal coverage to over 90% of the nation (Figure 3). A minimum number of additional DGPS reference stations would be required to complete the nationwide coverage and realize completion of the NNPS.

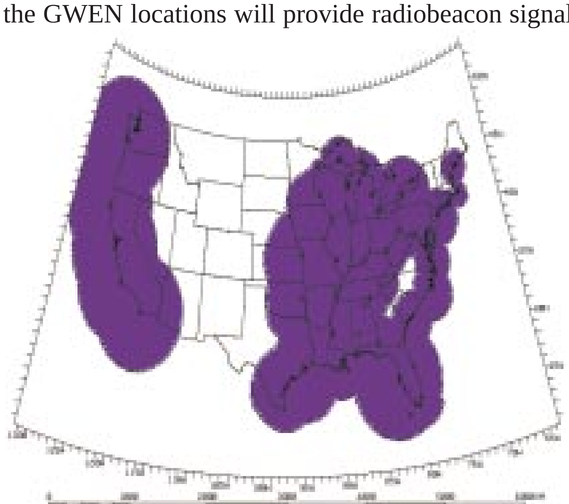

Figure 2. Existing DGPS signal coverage.

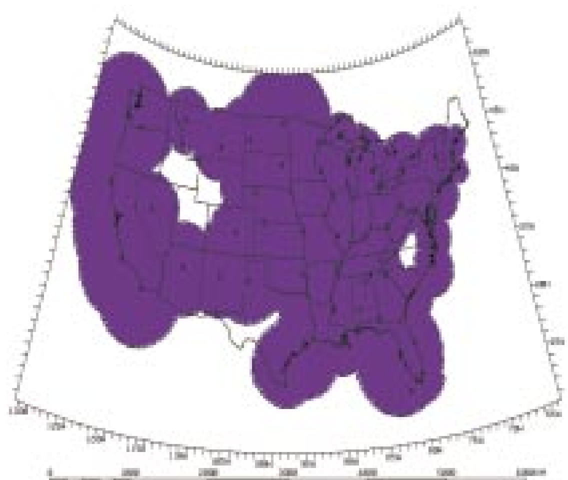

Figure 3. DGPS signal coverage with GWEN.

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PCS Networks

Outputs

- Code-division multiple access and PCS 1900 noise models.
- Interference simulation for PCS 1900 evaluation.
- Technical report on noise/interference modeling.

Wireless communications technologies have an almost unlimited growth potential, both in the United States and in the larger global economy. Networks that provide personal communications services (PCS) will figure prominently in this growth: the worldwide market for PCS equipment is in the billions of dollars. The Federal Government is providing spectrum for PCS communications and expects to make extensive use of emerging PCS networks in meeting its own wireless communication needs. However, effective implementation of PCS networks will require careful matching of PCS equipment capabilities with planned applications. The facilities currently available for evaluating emerging PCS technologies are limited. The Institute's PCS Networks program is contributing to development of the necessary PCS evaluation tools.

The overall scope of the PCS Networks program is illustrated in Figure l. A particular goal is to develop accurate means of assessing interference effects, which are expected to be a key limiting factor in the deployment of PCS. During FY 96, ITS engineers developed network-level interference models for global system for mobile (GSM) communications-based and IS-95-based PCS technologies (Block 1 of Figure 1), and began implementing these interference models (and associated propagation models) in commercially available waveform generation and simulation equipment (Blocks 2 and 3). This effort will lead, in FY 97, to a real-time link simulator that will be useful in testing the interoperability and performance of a wide variety of PCS and other wireless communications systems (Blocks 4 and 5). Because the interference and channel propagation simulators are programmable, the integrated simulation system will be capable of emulating the interference and propagation environment of essentially any wireless communication system. The propagation models being used were developed by ITS under PCS projects described in the Applied Research section of this report (page 57).

The other blocks in Figure 1 show other aspects of the PCS Networks program including the PCS Standards program. During FY 96, Institute staff continued to participate in the development of unlicensed PCS standards through contributions to Telecommunications Industry Association (TIA) Committee TR41.6. Unlicensed PCS technologies are expected to enhance the economy and flexibility of customer premise distribution systems by eliminating wiring costs and constraints on the location of telecommunication terminals within buildings. Under the sponsorship of the Department of Defense, the Institute participated actively in defining Federal user requirements and proposed technology solutions for unlicensed PCS equipment. This equipment is being standardized by the TIA TR41.6 committee for operation in the recently allocated 1910- to 1930-MHz frequency band. In their present form, the unlicensed PCS standards are suited primarily for wireless private branch exchange voice services, but all contain provisions for the addition of data services. Institute staff members contributed to proposed technology solutions for wireless user premises equipment including STU-III equipment.

Figures 2 and 3 show outputs of the ITS-developed network-level PCS interference model for a GSM-based system known as PCS 1900. Both figures show the simulation of the PCS 1900 uplink interference waveform caused by eight mobile stations in each of six nearby interfering cells, as seen at the primary cell's base station receiver. In Figure 2, the transmitted power levels of the interfering mobile stations have been made equal—an assumption often made by PCS system designers. As expected, the resulting voltage envelope distribution appears Rayleigh distributed, although it is somewhat distorted in form because of the relatively small number of interferers. In Figure 3, the transmitted power level of one interfering mobile station has been increased by a factor of 10. The graph clearly demonstrates that the voltage envelope is no longer Rayleigh distributed; it also illustrates the strong effect a single dominant interferer can have. The model's ability to accurately represent a variety of real-world interference conditions should make it useful in assessing and optimizing PCS network performance.

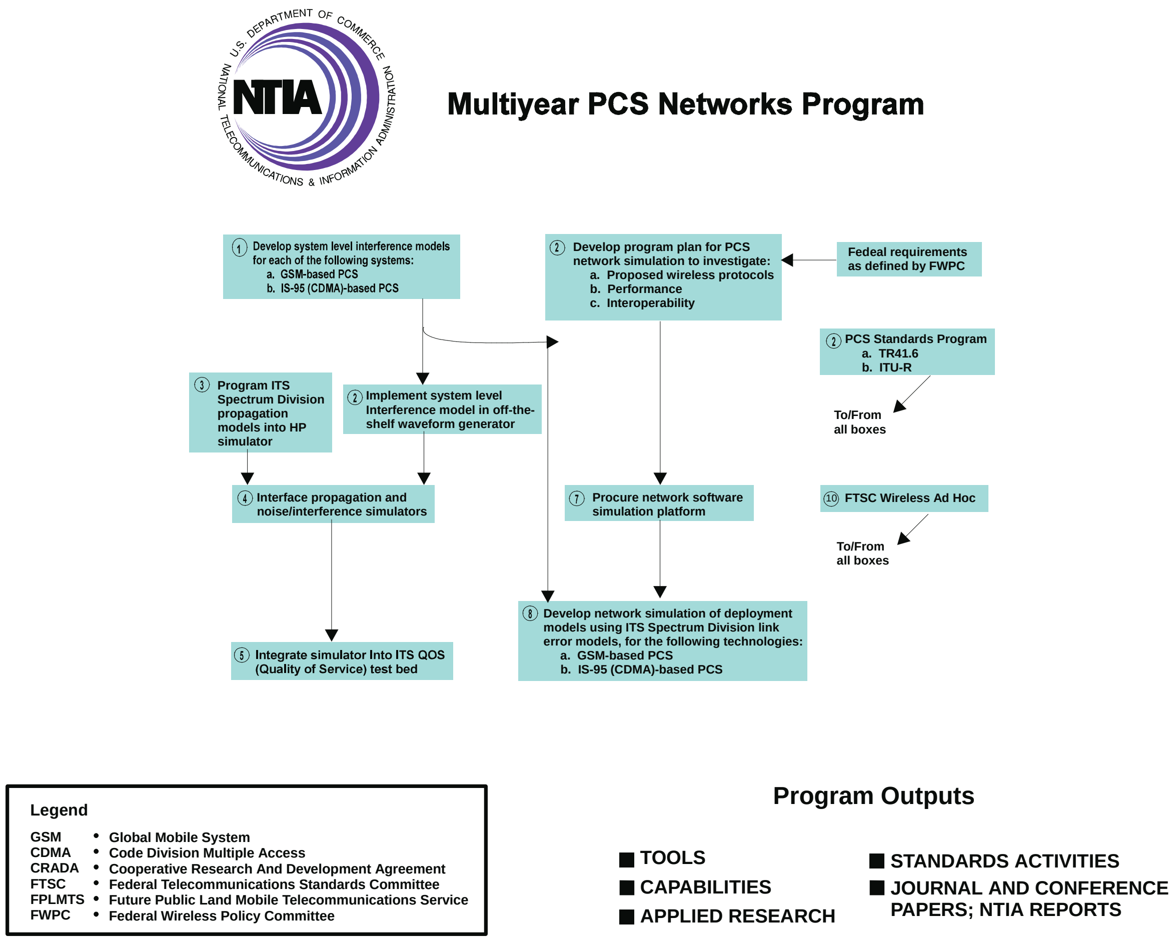

Figure 1. Multiyear PCS Networks program.

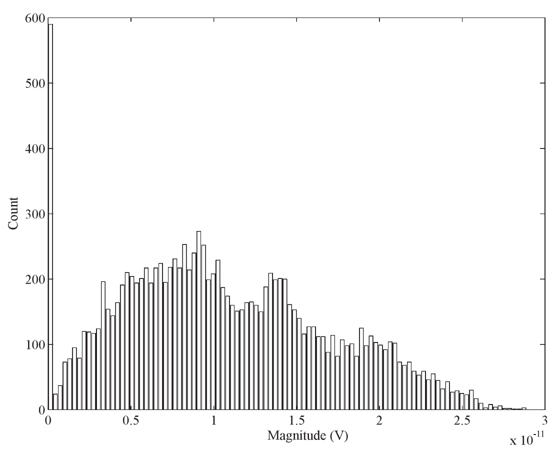

Figure 2. Voltage envelope histogram.

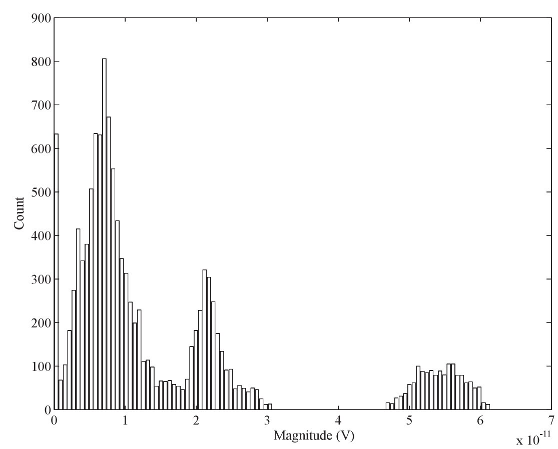

Figure 3. Voltage envelop with the addition of a single dominant interferer.

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